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Insight into the development of non-adherent, absorbent dressings.

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• **Objective:** This study aimed to develop a variety of wound dressing materials, made from standard natural fibres, that have high absorption and non-adherent characteristics.
• **Method:** A total of 21 dressings were made using knitted and crochet technologies and their absorbency was tested. Five non-adherent recipes were selected from a range of chemical formulations and the optimised non-adherent finishes were applied to the four best dressings. Their absorbency and non-adherent properties were evaluated.
• **Results:** The study demonstrated that rib cotton (RC), rib viscose (RV), crochet cotton medium (CCM) and crochet viscose medium (CVM) dressings possess high absorption and that five finishing recipes, C+D, A+G, I, I+N and I+G, impart high absorption as well as non-adherent properties. The finish I+G is superior in imparting non-adherence to RV dressing, both in dry and moist conditions. This means that irrigation with water, saline or sodium citrate solution before removing the dressing from a wound is not needed.
• **Conclusion:** A number of novel knitted and crochet structures with enhanced absorbency have been designed for wound management using standard bleached fibres. Novel non-adherent finishes for the developed structures have been formulated for the developed dressings, and offer an alternative to existing non-adherent dressings.
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absorbency; British Pharmacopoeia method; wound dressing

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Most of the non-adherent dressings in the *Drug Tariff* are either non-absorbent or absorb insufficient fluid. This research therefore set out to develop novel dressing materials that possess both high absorption and non-adherent characteristics. A number of knitted and crochet dressings with enhanced absorbency and non-adherent finishes were tested and evaluated. The results are published here. It should be borne in mind, however, that these materials have not yet undergone clinical trails to establish their application and safety, although these are planned.

Wound dressings

Wound healing is a natural process that can be enhanced by some dressings. These should be easy to apply and painless to remove. They should also help to create an optimal environment for wound healing and require fewer changes, thereby reducing nursing time.[1-3] Modern dressings generally comprise absorbent layers held between a wound contact layer and a base material. The absorbent layers absorb blood, fluids and exudate. The wound contact layer is low-adherent and can be removed without disturbing new tissue growth.

Method

Knitted and crochet structures

Normally a combination of non-adherent dressing and an absorbent pad is used to treat open wounds. This research has developed a single dressing material that carries out both functions.

Twenty-one structures were produced using single-jersey, interlock, rib and crochet machines (Box 1). Fibres used were bleached cotton, bleached viscose and bleached Tencel.

Absorbency

The absorbency of any dressing depends on the properties of its fibres and their ability to hold or store the absorbed liquid. In our experiment, the absorbency of the knitted and crochet samples before and after treatment with non-adherent finishes was determined by the following two methods:

• **Demand absorption** The absorption capacity (DAC, g/g) and the rate of absorption (DAR, $g/m^2/s$) of the specimens were determined using computerised Demand Wettability Apparatus. The test procedure, developed at Bolton Institute, is described in depth elsewhere.[4] Distilled water and saline (0.9%) were used as absorbent liquids.

• **British Pharmacopoeia (BP) method** This method,[5] which involves sodium chloride and calcium chloride solutions, calculates absorbency by placing a weighed 5 x 5cm specimen in a petri dish. A volume (equivalent to 40 times the mass of a sample) of preheated (37°C) solution is added and allowed to stand for 30 minutes at this temperature. Using forceps, the specimen is then suspended by one corner for 30 seconds and weighed. The difference in mass before and after the test is defined as

Box 1: Structures produced for the study

SJPC	Single jersey plain cotton
SJKTC	Single jersey knit and tuck cotton
RC	Rib cotton
IC	Interlock cotton
CCO	Crochet cotton open
CCM	Crochet cotton medium
CCD	Crochet cotton dense
SJPV	Single jersey plain viscose
SJKTV	Single jersey knit and tuck viscose
RV	Rib viscose
IV	Interlock viscose
CVO	Crochet viscose open
CVM	Crochet viscose medium
CVD	Crochet viscose dense
SJPT	Single jersey plain Tencel
SJKTT	Single jersey knit and tuck Tencel
RT	Rib Tencel
IT	Interlock Tencel
CTO	Crochet Tencel open
CTM	Crochet Tencel medium
CTD	Crochet Tencel dense

the amount of water absorbed and retained by the specimen. The BP method was used because it uses sodium and calcium solutions, which resemble artificial blood, at body temperature.

Peel test

The adherence of both finished and unfinished fabrics was tested and assessed by modified 180° peel test using a peeling tester. The 180° peel test is a common test used to determine the adhesive strength of bonded strips such as metals and paper.

Two ml of gelatin solution, prepared by dissolving 57.5 parts of distilled water, 40 parts of gelatin and 2.5 parts of glycerin in a water bath at 60°C, was applied to one ply of gauze fixed on a rectangular stainless-steel plate. The test specimen was placed over this for one minute at 20°C. The prepared gauze, gelatin solution and dressing specimen was placed between the peeling paper and the steel plate and a mass of 1kg was kept in the middle of the specimen for 10 minutes. The specimen was removed and dried at 85°C in a temperature-controlled bath for 30 minutes. The dried and conditioned specimen was tested for its peel strength. The wet peel strength was also tested after the specimen was moistened with 1ml of distilled water.

Results and discussion

Effect of structure on absorbency

The absorbency of the developed structures (single layer) is given in Figs 1–6. Cotton and viscose fibres possessed good absorbency, as did the SJKTC, CCO and CCM structures. There was either no or an insignificant difference between the uptake of water and saline, irrespective of the structure.

Relationship between absorbency and number of layers

To establish the relationship between absorbency (g/g) and the number of layers, the BP test method was used on SJKTC and standard cotton gauze. SJKTC was chosen because it absorbed more of the Na^+ and Ca^{++} ions solution than all of the other structures (Fig 4). In SJKTC an increased number of layers did not influence absorption (g/g), in contrast to cotton gauze (Tables 1 and 2).

In order to prove the BP method is not an appropriate test method for determining the absorbency of open-structure cotton gauze in g/g, the results were converted into g/25cm² (the area of the test specimen taken for absorbency measurements) and g/100cm², as stipulated in the BP method.

The results reveal there was a correlation between absorbency in g/area (g/25cm² and g/100cm²) and the number of plies in both cotton gauze and SJKTC: the greater the number of plies, the greater the absorbency. The results were statistically analysed and good linear relationships were found between absorbency of cotton gauze (g/100cm²) and the number of plies (coefficient correlation $r=0.996$) and between the absorbency of SJKTC and the number of plies (coefficient correlation $r=0.999$). The results clearly showed that absorbency expressed in g/g is misleading.

The result obtained with the BP test method is based on the increase in the mass of the specimen after immersion in a solution containing Ca^{++} and Na^+ ions for 30 minutes. As the structure of cotton gauze is more open than SJKTC, the final mass of the sample includes the mass of water present in the interstices (gaps) between the yarns. Additionally, a mass of water will be absorbed by the yarn, although this is limited due to the closeness of the fibres in the cotton yarn. When the number of layers in cotton gauze increases, the chance of water becoming trapped in the open spaces also increases. Ultimately, the final mass of the specimen will increase, resulting in a higher g/g. As the structure of SJKTC is not as open as cotton, virtually no water collects in the interstices between yarns.

If pressure is applied on open cotton gauze while it is in use, the water or solution present in the interstices will seep out. Furthermore, SJKTC and other structures retain more water, solution or exudate than open cotton gauze.

The absorbency (g/100cm²) of eight-ply cotton gauze was equivalent to that (g/100cm²) of one-ply SJKTC. In other words, absorbency of eight-ply SJKTC increases by about eight times that of eight-ply cotton gauze. Dressings that absorb 12g/100cm² of liquid containing Na^+ and Ca^{++} ions are classified as high absorbent.[5]

Fig 1. Effect of structures on absorbency (DAC) of cotton dressings (single layer)

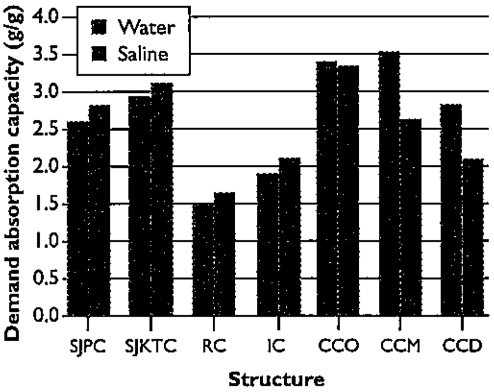


Fig 2. Effect of structures on absorbency (DAC) of viscose dressings (single layer)

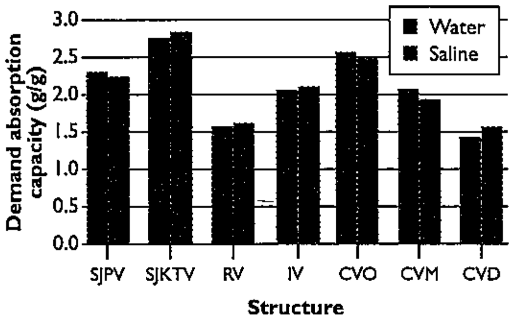


Fig 3. Effect of structures on absorbency of Tencel dressings (single layer)

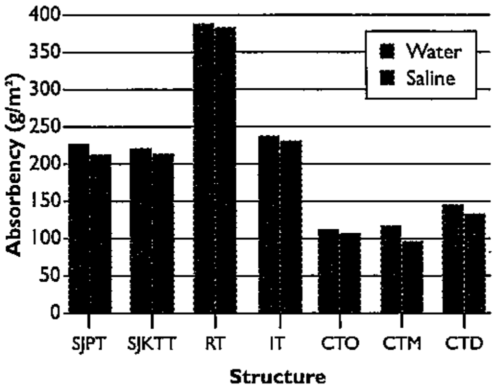


Fig 4. Effect of structures on uptake of liquid containing Na^+ and Ca^{++} ions: cotton dressings (single layer)

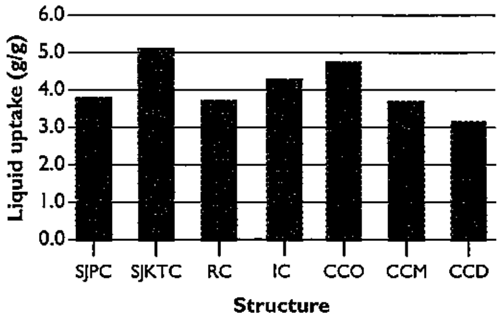


Fig 5. Effect of structures on uptake of liquid containing Na^+ and Ca^{++} ions: viscose dressings (single layer)

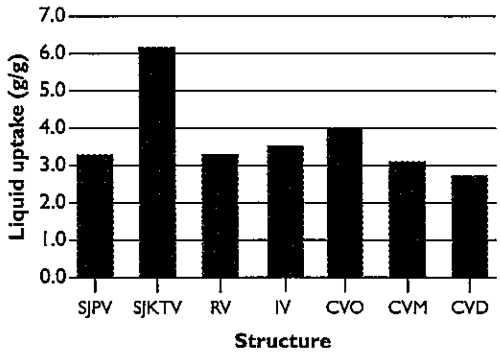
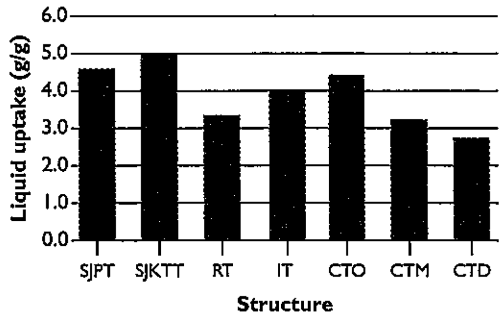


Fig 6. Effect of structures on uptake of liquid containing Na^+ and Ca^{++} ions: Tencel dressings (single layer)



Non-adherent finish

• **Chemical formulation** Considerable research and development work was undertaken to formulate a recipe that meets the following requirements:
• Produces gels on dressings that facilitate non-traumatic dressing removal
• Maintains a moist environment at the wound site
• Enhances the absorption of body fluid
• Must not be toxic, irritant or allergenic to humans.

Several chemicals and chemical compositions were screened, investigated and assessed. To protect confidentiality, the ingredients of the recipe are not disclosed here and general identifications of the chemicals are given instead. The sponsor is preparing an application for a patent for this invention.

After combining different compounds and modifying recipes, a final solution consisting of a synergistic system of chemicals with their optimised

Table 1. Absorbency of SJKTC (BP method involving Ca^{++} and Na^{+} ions)

No. of ply	Initial weight (g)	Final weight (g)	Liquid absorbed (g)	Absorbency (g/g)	Absorbency ($g/25cm^2$)	Absorbency ($g/100cm^2$)
1	0.5463	3.4086	2.8623	5.2	2.9	11.4
2	1.0785	7.0350	5.9565	5.5	6.0	23.8
3	1.618	10.1880	8.5700	5.3	8.6	34.3
4	2.1361	14.5540	12.4179	5.8	12.4	49.7
5	2.7212	18.3260	15.6048	5.7	15.6	62.4
6	3.2769	21.1715	17.8946	5.5	17.9	71.6
7	3.7353	24.2964	20.5611	5.5	20.6	82.2
8	4.2843	28.2119	23.9276	5.6	23.9	95.7

Table 2. Absorbency of standard cotton gauze (BP method involving Ca^{++} and Na^{+} ions)

No. of ply	Initial weight (g)	Final weight (g)	Liquid absorbed (g)	Absorbency (g/g)	Absorbency ($g/25cm^2$)	Absorbency ($g/100cm^2$)
1	0.0425	0.2572	0.2147	5.1	0.2	0.9
2	0.0819	0.5586	0.4767	5.8	0.5	1.9
3	0.1257	0.9294	0.8037	6.4	0.8	3.2
4	0.1661	1.3660	1.1999	7.2	1.2	4.8
5	0.2113	1.8840	1.6727	7.9	1.7	6.7
6	0.2424	2.1988	1.9564	8.1	2.0	7.8
7	0.2924	2.8201	2.5277	8.6	2.5	10.1
8	0.3309	3.2381	2.9072	8.8	2.9	11.6

dosages was developed. Recipes C+D, A+G, I, I+N and I+G possessed high absorption and gelling properties, as well as non-adherent characteristics, fulfilling the above criteria.

The RC, RV, CCM and CVM structures were padded using the recipes and dried at 60°C for 30 minutes. Their selection was based on current as well as other test results, such as fabric weight, flexibility and lint formation, not covered in this paper.

As demonstrated in Figs 7 and 8, the non-adherent finishes did not hinder the high-absorption properties of RC and further enhanced absorption in CCM. The finishes increased the rate of absorption. Similar results were obtained with RV and CVM.

The peel test was carried out on the finished RV to determine the level of the adherence. Unfinished RV was used as a control. Specimens were tested dry and after being moistened with water for one minute. This reflects usual practice for a number of dressings.

Table 3 shows that, compared with the unfinished dressing, the level of adherence of all the finished dressings reduced considerably in the dry condition. However, specimens C+D and I were still adherent when moist.

C+D and I either did not produce enough gel or produced sticky substances that enhanced adherence when moist. However, a 46% improvement in non-adherence was achieved in the sample finished with I+G. This sample also had the highest non-adherence in the dry state as the reduction in peeling load was around 47%.

The data in Table 3 indicate that the finish I+G is superior in imparting non-adherent characteristics to the dressing both in the dry and moist conditions. The results also indicate that it is not necessary to irrigate with water, saline or sodium citrate solution before removing a dressing finished with I+G from the wound. However, clinical trials are required to substantiate these results.

Conclusion

The outcomes highlighted a number of research issues that have helped to engineer the right products for a specific application. A number of

Fig 7. Absorbency of non-adherent finished rib cotton (RC) dressing

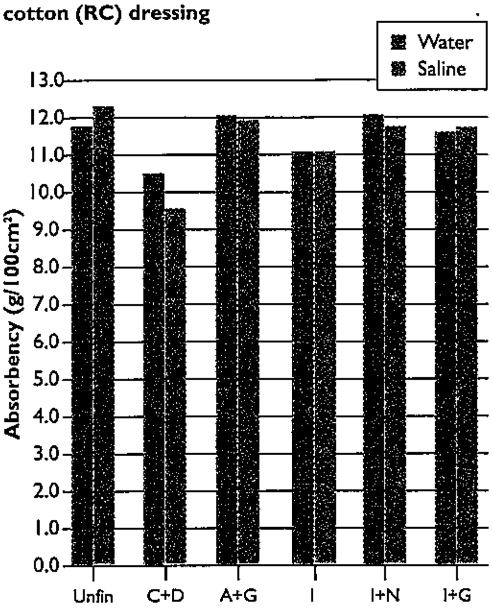


Fig 8. Absorbency of non-adherent finished crochet cotton medium (CCM) dressing

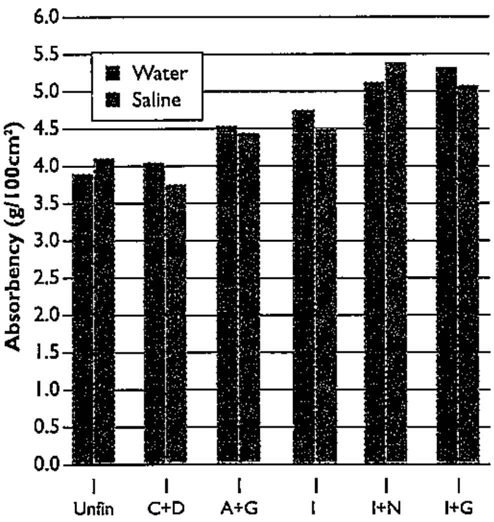


Table 3. Effect of non-adherent finish on RV dressing

Particulars	Peel load (Kgf) Dry	Peel load (Kgf) Moist
Unfinished RV	6.78	2.83
C+D	5.72	3.78
A+G	4.35	2.22
I	5.44	3.19
I+N	4.43	2.84
I+G	3.58	1.53

Concentration of C = 3% and D = 2%
Concentration of A = 2% and G = 3%
Concentration of I = 0.5%
Concentration of I = 0.5% and N = 2%
Concentration of I = 0.5% and G = 2%

Box 1. Summary of the main findings

This article describes a study in which a number of knitted and crochet dressings with enhanced absorbency were developed from bleached cotton, viscose and Tencel fibres. Novel non-adherent finishes for the developed structures were formulated using chemicals that are safe to use on human skin

The absorption and non-adherence characteristics of the finished materials were tested and evaluated. The developed dressings were found to be both non-adherent and high-absorbent, as well as soft

The authors say these research results indicate that these dressing materials can be used on both acute and chronic wounds. Unlike alginates, they are not suitable for cavity wounds as cotton, viscose and Tencel fibres are not absorbed by the body at a sufficiently fast rate

Since these dressings are non-adherent, it should be possible to use them on epithelialising wounds. Their high absorption properties mean they should be suitable for moderate and heavily exuding wounds

A randomised controlled trial is needed to investigate the safety and efficacy of these dressing materials for use in practice

novel knitted and crochet structures with enhanced absorbency have been designed for wound management. Novel non-adherent finishes for the developed structures have been formulated, and offer an alternative to existing non-adherent dressings. The benefits are:

• High absorbent capacity and absorption rate which promote free flow of body fluids and prevent fluid pooling at the wound site, reducing the risk of bacterial infection and wound maceration
• Gelling facilitates non-adherence to the wound, resulting in non-traumatic dressing removal. It also maintains a moist environment
• The products are soft and easy to handle — there is no gelling in the dry state. They can also be used on dry wounds, unlike alginate dressings
• A range of novel structures and finishing compounds have been developed and characterised by using conventional and relatively inexpensive fibres, equipment and chemicals. ■

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